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USE OF FREE RANGING AMERICAN KESTRELS AND NEST BOXES FOR CONTAMINANT RISK ASSESSMENT SAMPLING: A FIELD APPLICATION

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ABSTRACT.—From 1989–92, American kestrels (*Falco sparverius*) were studied as part of a contaminant risk assessment in southern Iowa. Blood, fecal-urate, esophageal constriction and footwash samples were collected for chemical analyses to evaluate exposure of kestrels to an organophosphorus insecticide. To increase the number of kestrels available for sample collection, a nest box program was established. Of 56 boxes erected, 66% (37) were occupied one or more years. Mayfield nest success estimates were not statistically different between 1991, when intensive nest box monitoring and sample collection occurred (61.9%, 95% CI = 44.0–86.8%, N = 23), and 1992 when box monitoring was less intense and no biological samples were collected (56.4%, 95% CI = 29.0–108.9%, N = 15). No significant difference was detected in reproductive measurements between 1991 and 1992 (clutch size $Z = -0.37$, df = 40, $P = 0.71$; brood size $Z = -1.06$, df = 28, $P = 0.29$; number fledged/occupied box $Z = 0.04$, df = 39, $P = 0.97$; number fledged/successful box $Z = -0.58$, df = 26, $P = 0.56$). Combining 1991 and 1992 data, we found nests that failed to hatch were visited significantly more often during the pre-hatch period ($\bar{x} = 3.82$ visits per box) than hatched nests ($\bar{x} = 1.91$ visits per box; F = 4.06, df = 1,44, $P = 0.05$). Our data do not indicate that disturbance from intensive biological sampling substantially decreased American kestrel post-hatch nesting success. However, pre-hatch visits should be limited to prevent nest failure. Most nesting variables recorded in this study were similar to other studies where biological sampling disturbance did not occur.

KEY WORDS: *American kestrel; biological sampling; contaminant risk assessment;* Falco sparverius; *nest box; nest success.*

Uso de *Falco sparverius* libres y cajas anideras para muestreo de evaluación de riesgos por contaminante: una aplicación de campo

RESUMEN.—Desde 1989 a 1992, *Falco sparverius* fue estudiado como parte de mediciones de riesgo de contaminates en el sur de Iowa. Muestras de sangre, urato fecal, constricción esofageal y lavado de patas, fueron colectados para análisis químico con el fin de evaluar exposición de *F. sparverius* a un insecticidas organofosforado. Para incrementar el número de *F. sparverius* disponibles para colectar muestras, se estableció un programa de cajas anideras. De 56 cajas, el 66% (37) fueron ocupadas uno o más años. Estimaciones de éxito del nido no fueron significativamente diferentes entre 1991 (61.9%, 95% CI = 44.0–86.8%, N = 23) y 1992 (56.4%, 95% CI = 29.0–108.9%, N = 15). No se detectaron diferencias significativas en medidas reproductivas entre 1991 y 1992 (tamaño de nidada $Z = -0.37$, gl = 40, $P = 0.71$; tamaño de prole $Z = -1.06$, gl = 28, $P = 0.29$; número de volantones/caja ocupada $Z = 0.04$, gl = 39, $P = 0.97$; número de volantones/caja exitosa $Z = -0.58$, gl = 26, $P = 0.56$). Combinando los datos de 1991 y 1992, encontramos que la perturbación intensiva por muestreo biológico no causó la sustancial disminución de éxito de nidificación post-eclosión en *F. sparverius.* Sin embargo, visitas pre-eclosión podrían ser limitadas para prevenir el fracaso del nido. La mayoría de las variables de nidificación registradas en este estudio fueron similares a otros trabajos donde la perturbación por muestreo biológico no ocurre.

[Traducción de Ivan Lazo]

Because they occupy niches high on food chains and they are susceptible to bioaccumulation of environmental pollutants, raptors are often of special interest when conducting contaminant risk assessments. However, many species are difficult to study since they tend to nest at low densities and inhabit areas where access is difficult (Newton 1979). This limits the availability of samples and small sample sizes restrict statistical analyses. Selection of the American kestrel (*Falco sparverius*) as a bioindicator species alleviates many of these difficulties. The kestrel is ideal because it is sensitive to environmental contamination, has a wide geographical distribution, feeds on a broad range of prey items, occupies relatively small home ranges, and uses nest boxes (Roest 1957, Cade 1982, Wiemeyer and Lincer 1987, Bird and Palmer 1988, Hoff 1992).

American kestrels nesting in boxes have been used to study effects of organochlorines and other contaminants on reproduction (Lincer 1975, Henny et al. 1983, Hoff 1992). However, there is little documentation of field techniques used to monitor kestrels in contaminant risk assessments and how these techniques affect reproductive success. These are important considerations when designing assessments aimed at quantifying effects of contaminant exposure on nesting parameters. The first objective of this study was to describe how an American kestrel nest box program was implemented as part of a U.S. Environmental Protection Agency mandated Tier IV, Level II Ecological Risk Assessment (Kendall 1994) designed to evaluate wildlife exposure to an organophosphorus insecticide for corn rootworms (*Dibrotica* spp.). The second objective was to evaluate kestrel reproductive performance and the impact of intensive monitoring and biological sampling on nest success associated with the risk assessment.

STUDY AREA

The study area was located in southern Lucas and northern Wayne Counties in southcentral Iowa (40°57'N, 93°18'W). American kestrels winter and breed throughout the area (Dinsmore et al. 1984). Topography ranged from nearly flat upland areas to gently rolling hills cut by intermittent streams. Most upland areas were grazed by cattle or utilized for hay, corn (*Zea* spp.) and soybean (*Glycine* spp.) production. The risk assessment was conducted on nine privately-owned farm sites, each approximately 65 ha in area and bisected by a hedgerow. Farmland adjacent to each hedgerow was in corn production during 1989 and 1991 when an organophosphorus insecticide was applied. During 1990 and 1992, farmland adjacent to hedgerows was planted to corn or soybeans, or seeded to pasture and hay fields and no insecticide was applied.

METHODS

During the fall and winter of 1988–89, four wooden nest boxes (Henderson 1984) were attached to utility poles, windmills, barns or wooden posts 2.5–6.0 m above the ground, on or within 400 m of each study site (36 boxes total). During early spring of 1990, two additional cylindrical polyvinyl chloride (PVC) nest boxes (Pasa 1989) were attached to 5 m tall utility poles centrally located on each of the nine farm sites (18 additional boxes). Two supplementary PVC boxes were placed near the periphery of one site for a total of 56 boxes. We oriented boxes to the south or southeast to increase light penetration, discourage European starling (*Sturnus vulgaris*) nesting and lessen exposure to early spring northwest weather patterns (Curley et al. 1987, Toland and Elder 1987, Wilmers 1987). At each site, distances between adjacent boxes ranged from 179–1806 m. Mean distance between boxes per site ranged from 488–914 m.

Nest boxes were visited once prior to egg laying each year to clean, repair and add wood shavings as a nest substrate. Damage to boxes or poles prior to nesting prevented some boxes from being used in various years. We visited all boxes after each breeding season to determine use. Only visits made during nesting (eggs or nestlings present) were tallied for data analysis.

We conducted risk assessment research during the late spring and early summer of 1989 (10 April–19 July) and 1991 (2 April–10 July). Biological samples were collected for analysis of pesticide exposure (Hoff 1992). In 1989, occupied nest boxes were visited up to six times (0–3 prehatch visits per box and sampled up to five times during the nesting period). In 1991, occupied boxes were visited 2–12 times pre-hatch and sampled once every 4–5 d posthatch.

In 1989 we attempted to collect blood samples from all adult (when present) and nestling kestrels found in nest boxes. In 1991 we collected blood, fecal-urate, footwash, and esophageal constriction (crop) samples (Hoff 1992, Mellott and Woods 1993, Hunt et al. 1995). Samples were collected from two or three randomly selected nestlings in each occupied box. Most nestlings in successful boxes were sampled on six different occasions before they were 25 d old. Since kestrels can fledge prior to 24 d old (Bowman and Bird 1985), crop samples were not collected from nestlings older than 20 d to prevent escape of ligatured individuals. Footwash samples were collected exclusively from adult birds pre-hatch and posthatch. Nest boxes were not visited during the nesting cycle in 1990, but were visited up to four times each (0–3 pre-hatch visits) in 1992. No biological samples were collected in 1990 or 1992.

Growth measurements including rectrix length (Balgooyen 1976), upper mandible length and tarsus length were recorded for nestlings. Rectrices were measured in 1989, 1991 and 1992 to estimate age of young. The other growth measurements were compared between sampled and nonsampled birds to assess effects of the pesticide treatment in 1991 (Hoff 1992).

In 1989, nest box visits to collect blood samples were usually less than 1 hr in length. In 1991, our sampling regime required that each box be entered twice during each sampling session. To begin a session at a box, we removed all nestlings. Esophageal constriction ligatures and fecal-urate collection diapers were attached to randomly selected young (Hoff 1992, Mellott and Woods 1993, Hunt et al. 1995). We returned nestlings to their boxes and withdrew from the immediate area to allow feeding of young by the adult birds. After a 2-hr feeding period, nestlings were again removed from their box for collection of esophageal constriction samples, fecal-urate

Table 1. American kestrel reproductive success, nest box visitation, and biological sampling data collected in southern Iowa, 1989–1992.

	1989	1990	1991	1992	$\bar{x}$ ALL YEARS
Boxes examined	36	53	56	55	50
% Boxes occupied (*N*)	22 (8)	21 (11)	41 (23)	42 (23)	33 (65)
Apparent nest success (*N*)	63 (5)	91 (10)	65 (15)	78 (18)	74 (48)
$\bar{x}$ clutch size (*N*)	4.7 (7)	—	4.4 (23)	4.4 (19)	4.4 (49)
$\bar{x}$ % hatching success	64 (21/33)	—	70 (71/101)	67 (56/83)	68 (148/217)
$\bar{x}$ brood size	4.2 (21/5)	—	4.4 (71/16)	4.0 (56/14)	4.2 (148/35)
$\bar{x}$ % fledging success	100 (21/21)	—	86 (61/71)	89 (50/56)	89 (132/148)
$\bar{x}$ number fledged/occupied box	2.6 (21/8)	—	2.7 (61/23)	2.8 (50/18)	2.7 (132/49)
$\bar{x}$ number fledged/successful box	4.2 (21/5)	—	4.1 (61/15)	3.8 (50/13)	4.0 (132/33)
$\bar{x}$ number of visits/occupied box	2.5 (20/8)	—	9.1 (209/23)	1.6 (36/23)	4.9 (265/54)
$\bar{x}$ number of visits/successful box	3.6 (18/5)	—	10.9 (163/15)	1.6 (29/18)	5.5 (210/38)
$\bar{x}$ number of samples/occupied box	6.0 (48/8)[a]	—	18.6 (428/23)[b]	—	15.4 (476/31)
$\bar{x}$ number of samples/successful box	9.2 (46/5)	—	26.3 (395/15)[c]	—	22.1 (441/20)

[a] Includes 48 blood samples.
[b] Includes 229 blood, 82 fecal-urate, 77 esophageal constriction, and 40 footwash samples.
[c] Includes 214 blood, 76 fecal-urate, 70 esophageal constriction and 35 footwash samples.

samples, blood samples and morphological data. Nestlings were then returned to their nest boxes. The entire sampling process required 3–3.5 hr to complete. Each session was tallied as one nest box visit.

Occupied boxes were defined as those in which at least one egg was laid. Successful boxes were those that fledged at least one young. Apparent nest success was the number of nests fledging at least one young divided by the number of observed nest initiations. Percent hatching success was defined as the number of hatched eggs per number of eggs laid. Percent fledging success represented the percent of young hatched that fledged. Boxes in 1990 were determined occupied and successful if a mat of compressed pellets lined the floor, fecal whitewash coated the interior walls and roof, and no kestrel carcasses were present. Though subjective, our experience indicated that this was a reliable method in determining nest success. With use of this method some nests initiated and lost during the egg or early brood-rearing stage may not have been detected.

We used the Mayfield Model to estimate and compare nest success between 1991 and 1992 (Mayfield 1975, Steenhof 1987, Varland and Loughin 1993, Jacobs 1995). Data from 1989 and 1990 were excluded due to small sample size.

A Wilcoxon rank-sum test was used to compare measures of reproductive success (clutch size, brood size, number fledged/occupied box and number fledged/successful box) between 1991 and 1992, using control site data only (PROC NPAR1WAY, SAS Institute Inc. 1987). Data from both years were then pooled and ranks assigned to the measures. A nonparametric analysis of variance tested for differences between treated sites and those without pesticide treatments (PROC RANK and GLM, SAS Institute Inc. 1987).

The comparison of reproductive measures between 1991 and 1992 was repeated using the Wilcoxon rank-sum test for all data (treatment and control sites combined). Additionally, the number of pre-hatch visits per nest box were assigned ranks (PROC RANK, SAS Institute Inc. 1987) and a nonparametric analysis of variance tested for differences between hatched and unhatched nests (PROC GLM, SAS Institute Inc. 1987). The same procedure compared the number of post-hatch visits of successful nest boxes between 1991 and 1992.

RESULTS AND DISCUSSION

Nest Box Use. The use of nest boxes increased substantially between 1989 and 1992 (Table 1). Of 56 boxes erected, 66% (37) were occupied one or more years. Of boxes used, 60% were occupied by kestrels two or more years, only one box was occupied all 4 yr.

A gradual increase in kestrel nest box occupancy rates can be expected over the first few years after box placement. Occupancy rate is an important consideration for risk assessments since newly established boxes provide fewer nests for sampling than boxes available more than one nesting season. Hamerstrom et al. (1973) reported an increase in box occupancy from 20% in 1968 to 30% in 1971 in central Wisconsin. Bloom and Hawks (1983) documented nest box use in California increasing steadily from 20% in 1977 to 38% in 1980, similar to the rate increases observed during our study.

Mean nest box occupancy (Table 1) in our study was comparable to other multi-year investigations (Hamerstrom et al. 1973, 26%; Bloom and Hawks 1983, 31%). Stahlecker and Griese (1979) observed higher box use (73%) along a linear electrical transmission line. Varland and Loughin (1993) reported an average of 45% use on a linear highway route in Iowa.

European starlings were very common and persistently nested in boxes. This potentially reduced the number of boxes available to breeding kestrels (Cade 1982). Kestrel nests, however, were often initiated after starling nests were removed.

Nest Success. We felt it was important to determine the influence of intensive monitoring and sampling on reproductive success, as nest disturbance by observers could impact the reproductive parameters used to evaluate the effects of contaminant exposure. The comparison focused on 1991, a year of intensive monitoring and sampling, and 1992 when few visits were made to boxes. Based on apparent nest success, it might be concluded that increased monitoring and biological sampling in 1991 resulted in lower nest success (Table 1). However, apparent nest success can be inflated if nest visits are infrequent and nest failures are not detected, as was likely in 1992. The Mayfield Model of calculating nest success corrects for this bias. Mayfield nest success estimates were not statistically different between 1991 (61.9%, 95% CI = 44.0–86.8%, $N = 23$) and 1992 (56.4%, 95% CI = 29.0–108.9%, $N = 15$).

No significant difference was detected for measures of reproductive success between 1991 and 1992 on sites without pesticide treatment (clutch size $Z = -0.92$, df = 26, $P = 0.36$; brood size $Z = 0.0$, df = 18, $P = 1.00$; number fledged/occupied box $Z = -0.05$, df = 25, $P = 0.96$; and number fledged/successful box $Z = 0.23$, df = 17, $P = 0.82$). A second kestrel nest box study approximately 160 km north of our sites also found no difference between 1991 and 1992 reproductive measures (Varland and Loughin 1993). Therefore, data from both years were combined to test for an effect from pesticide treatment. No differences were detected between treated sites and those without pesticide treatments (clutch size F = 3.34, df = 1,40, $P = 0.08$; brood size F = 2.60, df = 1,28, $P = 0.12$; number fledged/occupied box F = 0.00, df = 1,39, $P = 0.98$; and number fledged/successful box F = 0.41, df = 1,26, $P = 0.53$), thus treatments were combined for further analyses. With treatments combined we detected no differences between 1991 and 1992 reproductive measures (clutch size $Z = -0.37$, df = 40, $P = 0.71$; brood size $Z = -1.06$, df = 28, $P = 0.29$; number fledged/occupied box $Z = 0.04$, df = 39, $P = 0.97$; number fledged/successful box $Z = -0.58$, df = 26, $P = 0.56$).

Even with intensive human disturbance and biological sampling, most nesting variables recorded in this study were similar to other studies where biological sampling disturbance did not occur. Mean clutch size (Table 1) was similar to that reported by Smith et al. (1972; $\bar{x} = 4.7$), Craig and Trost (1979; $\bar{x} = 4.6$), Kellner and Ritchison (1988; $\bar{x} = 4.2$), Wheeler (1992; $\bar{x} = 4.7$) and Varland and Loughin (1993; $\bar{x} = 4.8$). We observed mean hatching success over all years that was lower than reported by Bloom and Hawks (1983; $\bar{x} = 79\%$), but higher than reported by Smith et al. (1972; $\bar{x} = 67\%$), Kellner and Ritchison (1988; $\bar{x} = 65\%$), and observed in another Iowa study (Varland and Loughin 1993; $\bar{x} = 62\%$).

Mean percent fledging success over the 3 yr of available data was within the range reported in other studies. Other researchers observed fledging success ranging from 28–91% (Smith et al. 1972, Kellner and Ritchison 1988, Wheeler 1992, Varland and Loughin 1993). Our observed mean fledging rates also were similar to other studies (Table 1). Other researchers reported ranges from 3.1–3.6 young/occupied box and 3.7–4.0 young/successful box (Hamerstrom et al. 1973, Bloom and Hawks 1983, Wheeler 1992).

Nest Visits. Our data indicate that kestrels may be more sensitive to nest disturbance during incubation than during the nestling stage as suggested by Kellner and Ritchison (1988), and Varland and Loughin (1993). Six of 7 (86%) nest failures in 1991 and 3 of 4 (75%) in 1992 occurred before hatch. Combining 1991 and 1992 data, we found nests that failed to hatch were visited significantly more often during the pre-hatch period ($\bar{x} = 3.82$) than hatched nests ($\bar{x} = 1.91$; F = 4.06, df = 1,44, $P = 0.05$). Since nest box visits are required during incubation to estimate hatch dates, we recommend development of a method to accurately estimate hatch date based on egg weight loss (Heck and Konkel 1985). Such a method may allow observers to estimate hatch date after only one pre-hatch nest box visit, thus reducing potential abandonment.

Kestrel nests that advanced to the nestling stage were not as likely to fail as pre-hatch nests and appeared more tolerant of observer disturbance. Successful boxes were visited significantly more often during the post-hatch period in 1991 ($\bar{x} = 7.27$)

than in 1992 ($\bar{x}$ = 1.22; F = 105.42, df = 1,31, $P < 0.01$), while overall Mayfield nest success was not different between years.

Nest Box Availability. When conducting an ecological risk assessment, it may be desirable to have more boxes available than will likely be used to give potential breeding pairs different options for nesting. Extra boxes may increase chances of attracting additional breeding pairs thus increasing the number of birds available for biological sampling.

Box placement is best determined in relation to study area size and shape. Varland et al. (1992) suggested spacing boxes no closer than 805 m along a linear roadside route. In contaminant studies like ours, where study site size is limited, a trade-off between providing maximum potential contaminant exposure of birds and maximum percent box occupancy and success may exist. Decreasing the distances between boxes may decrease occupancy and success rates (C.J. Henny unpubl. data), but also may increase the number of kestrels exposed to insecticide treatments and available for contaminant exposure analysis. Kestrels were most likely to be exposed to insecticide if nesting in the center of our sites. We felt it important to place more boxes in the interior of sites, even if some boxes were avoided or unsuccessful due to intraspecific territoriality caused by close box spacing. Forty percent (19 of 48) of our successful boxes were within 800 m of another successful nest, and 54% of occupied boxes within 800 m of a second occupied box were successful. The closest two successful boxes were 231 m apart. In a second pair of occupied boxes (232 m apart) only one was successful. For all sites combined, the mean distance between any two available boxes was 676 m and between any two successful boxes was 795 m. Others have recorded occupied nests 34 m (Nagy 1963), 12 m (Smith et al. 1972), 42 m (Balgooyen 1976) and 100 m (Craig and Trost 1979) apart, but did not report their success.

Our data do not indicate that disturbance from intensive biological sampling substantially decreased American kestrel post-hatch nesting success. Human disturbance does appear to negatively influence nesting success during the pre-hatch period. Pre-hatch visits should be limited to the minimum required to reliably estimate hatch dates. This tactic should reduce pre-hatch failures making more post-hatch nests available for examination and biological sampling.

American kestrel nest boxes provide a feasible method for increasing nests and birds available for intensive sampling during contaminant risk assessments and other ecological field studies. Reproductive parameters may be different between kestrel populations inhabiting nest boxes and those inhabiting natural nest cavities (Møller 1994). We assert that potential reproductive differences are not as relevant to risk assessments where treated and control sites are studied similarly.

Techniques developed recently for assessing wildlife exposure to organophosphorus compounds involve nonlethal sampling of biological fluids and waste products for analysis (Cobb and Hooper 1994). To increase sample sizes obtained from kestrel studies, a nest box route should be established preceding an impending study to encourage maximum occupancy rates. We suggest establishing a box route at least 1, preferably 2 yr prior to a field season when biological sample collection is planned.

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